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SPECIFICATION

PNEUMATIC TIRE

TECHNICAL FIELD

This invention relates to a pneumatic tire having effectively reduced rolling resistance and flat spot while maintaining tire noise, particularly road noise at low level.

BACKGROUND ART

In automobiles, particularly passenger cars, the improvement relating to the reductions of vibration, fuel consumption and pollution is violently promoted, and hence it is strongly demanded to more reduce noise exemplified by road noise, rolling resistance and flat spot of tires as compared with those of the conventional tire.

As the most fundamentally conventional method of reducing the road noise, there can be mentioned (1) a method of softening rubber in a tread portion of the tire, (2) a method wherein a form of a tire carcass is changed to enhance a tension of a belt, and (3) a method wherein full width or both end portions of cross belt layers, cords of which layers being crossed with each other, are held by a reinforcing layer of cords extending in a circumferential direction, e.g. nylon cord coated with rubber to enhance a circumferential rigidity of a belt, and a rubber coating strip of the cord is spirally wound in a widthwise direction of the tire for removing a joint portion of the reinforcing layer as disclosed in JP-A-6-24208.

However, these methods have merits and demerits together, so that they are actually applied by selecting or combining these methods in accordance with the use purpose. Particularly, the method (3) is widely known as a method of improving a high-speed durability rather than the reduction of the road noise, and is a reinforcing structure being particularly prevailing in the existing high-performance and high-quality tires.

Namely, the method (1) can reduce the road noise through the softening of the tread rubber, but largely lowers the wear resistance of the tread and also considerably deteriorates the steering stability, so that it is lacking in the practical use, and the method (2) can enhance the belt tension in the tire, but is inconvenient in the basic performance of the tire that the lateral rigidity and cornering

performance of the tire are lowered to contact a portion other than the tread portion with ground, and the method (3) has somewhat an effect of reducing the road noise in addition to the improvement of the high-speed durability, but can not be still satisfied even at this degree of the effect.

On the contrary, in a radial tire that "a belt reinforcing layer is arranged at an outer circumferential side of a belt layer on a whole and/or both end parts of a tread portion, and the belt reinforcing layer is formed by spirally and endlessly winding a narrow-width rubberized strip containing a plurality of fiber cords so as to arrange the cords substantially in parallel in a circumferential direction of the tire, and the cord of the belt reinforcing layer is an organic fiber cord, and further this fiber cord has an elongation of not more than 2.7% at 50±5°C under a load of 1.4 g/d and an elongation of 1.5-6.0% at 170±5°C under a load of 0.7 g/d" as disclosed in JP-A-9-66705, "the belt reinforcing layer is spirally wound at the whole of the tread portion and/or at a position near to both side end parts of the tread portion and further the modulus of the cord used in the reinforcing layer is enhanced to arrange a barrier-like reinforcing layer having a high tension in the circumferential direction of the tire, whereby the tensile rigidity of the tread portion in the circumferential direction is made larger to enhance a so-called hoop effect of the belt, so that vibrations based on large and small, uneven road surface during the running of the tire are hardly caught by the tread surface and hence vibrations transferred through side portion of the tire - a rim portion – a wheel to an interior of the vehicle body is decreased or the road noise is reduced", and also "vibrations based on the uneven road surface can be reduced by rendering the organic fiber cord in the belt reinforcing layer into an elongation of not more than 2.7% under a load of 1.4 g/d at a temperature applied to the belt reinforcing layer during the usual running of the tire or 50±5°C", and further "the shapability of the tire through vulcanization is made good by rendering the fiber cord in the belt reinforcing layer into an elongation of 1.5-6.0% under a load of 0.7 g/d at a temperature applied to the cords in the vulcanization building of the tire or 170±5°C and the properties of the belt reinforcing layer become uniform and the ground contacting property also becomes uniform, so that the road noise property, steering stability and resistance to uneven wear in the tire are improved".

Therefore, such a tire is possible to balancedly reduce the road noise and the rolling resistance as compared with the conventional tire.

However, the standard of the performances required for the tire tends to become severer every year, and in order to clear up such a standard, it is required to more improve the road noise and the rolling resistance.

In addition to the above, it is lately taken on importance to reduce a flat spot, i.e. a deformation produced in a cooled tire when the tire heated during the running is left to stand under the load.

When a low-elasticity, low-loss cord such as nylon cord is used in the belt reinforcing layer for the purpose of reducing the rolling resistance under such a situation, there is a problem that it is obliged to increase the road noise and the flat spot.

Based on a knowledge that it is effective to decrease the amount of the cords used in the belt reinforcing layer for reducing each of the rolling resistance and the flat spot, it is an object of the invention to provide a pneumatic tire in which the rolling resistance and the flat spot are effectively reduced while maintaining the road noise at approximately an equal level as compared with that of the radial tire described in the above publication by particularly making the cord diameter of the reinforcing cord while maintaining the modulus of elasticity in the belt reinforcing layer as a rubberized layer at approximately an equal level to that described in this publication, and it is another object of the invention to provide a pneumatic tire in which the durability of the belt reinforcing layer itself is largely improved.

DISCLOSURE OF THE INVENTION

The pneumatic tire, particularly pneumatic radial tire according to the invention comprises a belt comprised of two or more cord layers, cords of which layers being crossed with each other, superimposed at an outer circumferential side of a crown portion of a toroidally extending carcass, and a belt reinforcing layer comprised of one or more rubberized layers of reinforcing cords extending substantially in a circumferential direction of the tire and arranged at an outer circumferential side of the belt so as to cover at least one of approximately full belt width and each side region of the belt, in which the reinforcing cord is a polyethylene-2,6-naphthalate fiber cord having a total count of not more than 240 dtex.

In this tire, both the rolling resistance and the flat spot can be effectively reduced by decreasing the volume of the reinforcing cord while maintaining the tensile modulus of the belt reinforcing layer, i.e. tension in the circumferential direction at a level equal to that of the radial tire described in JP-A-9-66705 in order to realize the low road noise equal to that of this radial tire.

That is, the invention is based on the knowledge that when using the reinforcing cord of polyethylene-2,6-naphthalate fiber, it is examined to make the diameter of the reinforcing cord small while maintaining low road noise equal to that of the radial tire described in the above publication and hence the tension in the circumferential direction of the belt reinforcing layer and as a result, it can be easily realized by making the twisting coefficient large.

In the other tire according to the invention, the reinforcing cord is particularly constructed with the polyethylene-2,6-naphthalate fiber cord formed by twisting two yarns each having a count of 1000-1200 dtex at a twisting coefficient of 0.35-0.45.

By making the twisting coefficient large can be realized the low road noise at an end count of the cords of polyethylene-2,6-naphthalate fiber in the belt reinforcing layer equal to that described in the above publication, and as a result, the cord volume in the tire is largely decreased to effectively reduce the rolling resistance and the flat spot.

When the twisting coefficient is less than 0.35, the lowering of the adhesion property to the coating rubber becomes remarkable, while when it exceeds 0.45, the tensile modulus lowers and it is difficult to realize the low road noise to be targeted.

In this tire and the former tire, by rendering the total count of the polyethylene-2,6-naphthalate fiber cord into not more than 2400 dtex is sufficiently decreased the cord volume, whereby the reduction of the rolling resistance and the flat spot can be effectively realized. On the contrary, when the count of a unit yarn is less than 1000 dtex, it is difficult to hold the tensile modulus at a level equal to that of the cord described in JP-A-9-66705.

In these tires, it is preferable that the coating rubber for the reinforcing cord has a 100% modulus at 25°C of 2.0-4.0 MPa, preferably 2.5-3.5 MPa and a rebound resilience at 25°C of not less than 60%.

Since the polyethylene-2,6-naphthalate fiber cord is relatively high in the modulus, if the modulus of the coating rubber for the cord is made low, the deformation amount of the coating rubber becomes relatively larger than the deformation amount of the cord and hence there is a fear of causing a premature heat deterioration of the coating rubber resulted from the heat generation thereof, and also there is a fear of causing cord separation directly resulted from such a difference of the deformation amount. In the invention, therefore, the modulus of the coating rubber is made relatively high to advantageously mitigate the difference of the deformation amount between the rubber and the cord, and also the rebound resilience of the coating rubber is rendered into not less than 60% to advantageously suppress the self-heat generation of the coating rubber, whereby the thermal deterioration of the coating rubber and the separation of the cord accompanied therewith are effectively prevented to guarantee the sufficient improvement of the durability of the belt reinforcing layer itself.

More preferably, the reinforcing cord coated with rubber has an elongation of 1.0-2.0%, preferably 1.3-1.7% at room temperature under a load of 1.4×9.8 mN/d, an elongation of 1.5-3.5%, preferably 2.0-3.0% at 50±5°C under a load of 1.4×9.8 mN/d, and an elongation of 1.5-3.0% at 170±5°C under a load of 0.7×9.8 mN/d.

Further, the reinforcing cord coated with rubber is preferable to have an elongation of 1.5-2.5%, preferably 1.7-2.3% at room temperature under a load of 2.8×9.8 mN/d.

By making the elongation of the reinforcing cord coated with rubber at room temperature to a range of 1.0-2.0% can be enhanced the operability in the tire building and also the biting of the reinforcing cord into the belt and the like can be prevented.

Also, the low road noise during the running of the vehicle can be realized by making the elongation at 50±5°C, which is generally the heating temperature of the belt reinforcing layer during the running of the tire under loading, to a range of 1.5-3.5%.

Moreover, the reason why the load of 1.4×9.8 mN/d is a standard in the above both elongations is based on the fact that an input to the cord in the tire is about 1.4×9.8 mN/d.

In addition, the dimensional stability of the tire can be further enhanced by making the elongation at 170±5°C, which is the heating temperature of the belt reinforcing layer in the vulcanization of the tire, to a range of 1.5-3.0%.

As to such an elongation, the reason why the load of 0.7×9.8 mN/d is a standard is based on the fact that a force of enlarging the cord in the vulcanization is around 0.7×9.8 mN/d.

In such a tire, an end count of the reinforcing cords per a width of 50 mm is 40-70 cords, more preferably 45-60 cords. As the end count is increased, the modulus of elasticity of the belt reinforcing layer becomes high and hence it is possible to more reduce the road noise, but the inconvenience is caused in the rolling resistance and the flat spot. In the invention, therefore, the end count is limited to 40-70 cords, whereby the effective reduction of the rolling resistance and flat spot is attained while maintaining the road noise at a low level.

Moreover, when the end count is less than 40 cords, the rigidity in the widthwise direction (modulus) is lowered to deteriorate the road noise.

The belt reinforcing layer is preferable to be constituted with a ribbon-shaped strip having a width narrower than an arranging width of the belt reinforcing layer, which is formed by coating one or more reinforcing cords with rubber at a gauge of 0.85-1.0 mm.

When the belt reinforcing layer is formed by a winding structure of the ribbon-shaped strip of the rubberized reinforcing cord(s) or the like, if the gauge of the coating rubber is too thin, the reinforcing cord(s) tends to be bitten into the belt in the enlarging deformation of a green tire during vulcanization, and there is a fear of causing a separation failure of the belt from the bitten portion as a nucleus in a product tire. For this end, as a result that the presence or absence of the separation failure is examined by variously changing the gauge of the coating rubber, it could be confirmed that in case of using the reinforcing cord of polyethylene-2,6-naphthalate fiber, when the gauge of the coating rubber is within a range of 0.85-1.0 mm, the biting of the reinforcing cord into the belt can be advantageously suppressed.

Moreover, the reason why the gauge of 1.0 mm is an upper limit is due to the fact that when it exceeds the above value, the tire weight increases and the rolling resistance becomes high.

Preferably, the belt reinforcing layer is constructed with a structural body formed by spirally winding the narrow-width ribbon-shaped strip of the reinforcing cord(s) coated with rubber in the widthwise direction of the tire.

According to this structure, the joint part of the belt reinforcing layer extending on the circumference of the tread portion in the widthwise direction thereof can be eliminated to make the belt reinforcing layer sufficiently uniform over the full circumference, and also the function resulted from the properties of the reinforcing cord can be developed sufficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematically cross-sectional view of a main part of an embodiment of the tire according to the invention.

FIG. 2 is the same view as in FIG. 1 illustrating another embodiment of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

In FIG. 1, a belt 3 comprised of two belt layers 1, 2 as a cord layer, in which cords are crossed with each other between the layers and extend in opposite directions with respect to an equatorial plane of the tire, is arranged on an outer circumferential side of a crown region of a radial carcass not shown and extending toroidally as a whole. On an outer circumferential side of the belt 3 are successively arranged one belt reinforcing layer or so-called cap ply 5 comprised of reinforcing cords 4 extending substantially in the circumferential direction of the tire and coated with rubber, and a pair of belt reinforcing layers or so-called layer plies 6 of reinforcing cords 4 extending in the same direction. The reinforcing cord 4 in these cap ply 5 and the layer ply 6 is constituted with a cord formed by twisting two polyethylene-2,6-naphthalate fiber yarns each having a count of 1000-1200 dtex at a twisting coefficient of 0.35-0.45. Therefore, the reinforcing cord 4 has a total count of not more than 2400 dtex.

That is, the cord 4 is formed by cable-twisting two ply-twisted raw yarns together in an opposite direction in which a twisting coefficient T defined by the following equation is 0.35-0.45:

$$T = N \times (0.139 \text{ x } D/\rho)^{1/2} \times 10^{-3}$$

(wherein N: twisting number of cord (turns/10 cm), D: total decitex number of cord found, and ρ: specific gravity of cord).

Moreover, the production of such a fiber yarn is not particularly limited unless a production method of fibers for usual tire cord is used.

The thus constituted reinforcing cord 4 is preferable to have an elongation of 1.0-2.0% at room temperature under a load of 1.4×9.8 mN/d, an elongation of 1.5-3.5% at 50±5°C under a load of 1.4×9.8 mN/d and an elongation of 1.5-3.0% at 170±5°C under a load of 0.7×9.8 mN/d as a measure of modulus under rubber coating, and is more preferable to have an elongation of 1.5-2.5% at room temperature under a load of 2.8×9.8 mN/d.

Also, it is preferable that an end count of the reinforcing cords 4 per a width of 50 mm is a range of 40-70 cords.

As the properties of the coating rubber for the reinforcing cord 4, it is preferable that 100% modulus at 25°C is 2.0-4.0 MPa, particularly 2.3-3.5 MPa and the rebound resilience at 25°C is not less than 60% as previously mentioned.

The cap ply 5 and the layer ply 6, each consisting of the reinforcing cords 4 coated with rubber, are preferable to be constituted by winding a ribbon-shaped strip containing one or more reinforcing cords 4 coated with rubber at a thickness of 0.85-1.0 mm and having a width narrower than an arranging width of each of the cap ply 5 and layer ply 6. More preferably, each of the cap ply 5 and the layer ply 6 is constituted with a spirally wound structural body of the ribbon-shaped strip.

According to the pneumatic tire having the above construction, the rolling resistance and flat spot can be advantageously reduced while effectively suppressing the occurrence of road noise as previously mentioned under the actions of the cap ply 5 and the layer ply 6.

FIG. 2 is a view similar to FIG. 1 showing another embodiment of the invention, in which layer plies 7, 8 each consisting of two plies having the same construction as the above layer ply 6 are arranged at outer peripheral sides of both side regions of the belt 3.

The latter case can bring about substantially the same function and effects as in the former case.

Although the embodiments of the invention are explained with reference to the drawings, it is possible to arrange two or more plies as only the cap ply or add the cap ply to the structure shown in FIG. 2.

As a gas filled in the pneumatic tire according to the invention, there can be used not only ordinary air but also air having an oxygen partial pressure changed, an inert gas such as nitrogen or the like or a mixture thereof.

EXAMPLE

The invention will be described in detail with reference to the following examples.

However, the invention is not limited to these examples.

As the reinforcing cord used in the cap ply and the layer ply of these examples, nylon cord is 6,6-nylon made by Toray DuPont Co., Ltd. (trade name: Type 728), and polyester cord is polyethylene-2,6-naphthalate. In these examples are evaluated dtex of the cord, end count, properties of coating rubber for the reinforcing cord, and road noise, rolling resistance, flat spot and high-speed durability as a parameter of structure or the like of the belt reinforcing layer.

In all of example tires and comparative tires, a tire size is 195/65R14, and polyethylene terephthalate (PET) cords are used as a carcass cord, and the manufacture of the tire is carried out by setting vulcanization conditions to 167°C × 12 minutes, and post-cure inflation conditions to an internal pressure of 250 kPa and 23 minutes.

All of the manufactured tires have the same tubeless structure, in which the belt 3 is comprised of two steel cord belt layers 1, 2 (width of inner belt layer 1: 150 mm, width of outer belt layer 2: 140 mm), and steel cords used in the belt layers 1, 2 have 1×5×0.23 structure, and the end count is 34.0 cords/5 cm, and a cord angle of the inner belt layer 1 is 22 degrees upward to the left and a cord angle of the outer belt layer 2 is 22 degrees upward to the right viewing from the front of the tire, and thus the belt 3 is a cross belt.

[Test Method]

With respect to these tires, the road noise, rolling resistance and flat spot are evaluated by the following test methods.

Test for road noise

The tire assembled onto a rim of 6J-14 and inflated under an air pressure of 200 kPa is applied to each of four wheels of a sedan type passenger car having a displacement of 2000 cc and run on a test course for the evaluation of road noise under a load corresponding to two crewmen at a speed of 60 km/h,

during which total sound pressure (decibel) over a frequency of 100-500 Hz is measured by a collecting microphone attached to a central position in a support for back of a driver's seat. The road noise is evaluated from the measured value.

Test for rolling resistance

A deceleration speed is measured by inertia method when the tire is run on a rotating drum having a smooth steel face, an outer diameter of 1707.6 mm and a width larger than a maximum width of the test tire and capable of controlling a rotating speed to a constant level at a speed of 0-180 km/h under a load of 400×9.8 N, and the rolling resistance is evaluated from the measured value.

Test for flat spot

After the tire is mounted onto a vehicle and actually run for a given time to sufficiently raise the temperature and left to stand until the tire is completely cooled under loading, the flat spot property is evaluated by measuring the deformation of the tire as a change of roundness. That is, the roundness is measured before and after the loading, respectively, and the difference between t he measured values is detected as a flat spot amount.

High-speed durability

The tire assembled onto a rim of 6J-14 and inflated under an air pressure of 200 kPa is run at a speed of 150 km/h under a load of 520 kg for 30 minutes, and then a speed is increased every 6 km/h unless the trouble is not caused, and the test is stopped at a time of causing the trouble to determine a limit speed.

Moreover, as the properties of the reinforcing cord constituting the belt reinforcing layer, an elongation at 50±5°C under a load of 1.4×9.8 mN/d and an elongation at 170±5°C under a load of 0.7×9.8 mN/d are measured from a load-elongation curve of the rubber coated reinforcing cord according to a definition of JIS L1017 in an atmosphere temperature of a measuring condition by means of an autograph (made by Shimazu Corp.), and the measured values are made as a measure of modulus of elasticity.

Also, 100% modulus at 25°C of the coating rubber is determined by using a JIS No. 3 test specimen and measuring stress at 100% elongation thereof, and a rebound resilience of the coating rubber is determined by using a test specimen of type 1 and measuring a rebound height according to a definition of

JIS K6255 through a tripso-type rebound resilience testing device.

These evaluation results are shown in Tables 1 and 2. Moreover, all numerical values of road noise, rolling resistance, flat spot and high-speed durability in Table 1 are represented by an index on the basis that the comparative tire 1 is 100, and all of them in Table 2 are represented by an index on the basis that the comparative tire 3 is 100. The larger the index value, the better the property (low road noise, low rolling resistance, low flat spot and high durability).

Table 1

			Example tire 1	Example tire 2	Example tire 3	Example tire 4	Comparative tire 1	Comparative tire 2
Structure of belt reinforcing layer			FIG. 1	FIG. 1	FIG. 1	FIG. 1	FIG. 1	FIG. 1
Reinforcing cord	Material and count of cord		PEN 1100 dtex/2	PEN 1100 dtex/2	PEN 1100 dtex/2	PEN 1100 dtex/2	PEN 1670 dtex/2	66 nylon 1400 dtex/2
	End count (cords/50 mm)		50	58.8	50	50	50	50
	Modulus of elasticity of cord	50 ± 5°C 1.4 × 9.8 mN/d	2.4	2.4	2.4	2.4	2.2	8.0
		170 ± 5°C 0.7 × 9.8 mN/d	2.2	2.2	2.2	2.2	2.0	5.0
Coating rubber	100% modulus (MPa)		1.8	1.8	2.5	3.0	1.8	1.8
	Rebound resilience (%)		55	55	60	65	55	55
Twisting coefficient			0.41	0.41	0.41	0.41	0.49	0.49
Road noise (index)			100	103	100	100	100	96
Rolling resistance (index)			106	100	106	106	100	106
Flat spot (index)			104	102	104	104	100	93
High-speed durability (index)			102	105	110	112	100	102

Table 2

			Example tire 5	Example tire 6
Structure of belt reinforcing layer			FIG. 2	FIG. 2
Reinforcing cord	Material and count of cord		PEN 1100 dtex/2	PEN 1100 dtex/2
	End count (cords/50 mm)		50	58.8
	Modulus of elasticity of cord	50 ± 5°C 1.4 × 9.8 mN/d	2.4	2.4
		170 ± 5°C 0.7 × 9.8 mN/d	2.2	2.2
Twisting coefficient			0.41	0.41
Road noise (index)			101	104
Rolling resistance (index)			105	101
Flat spot (index)			103	102

			Comparative tire 3	Comparative tire 4
Structure of belt reinforcing layer			FIG. 2	FIG. 2
Reinforcing cord	Material and count of cord		PEN 1670 dtex/2	66 nylon 1400 dtex/2
	End count (cords/50 mm)		50	50
	Modulus of elasticity of cord	50 ± 5°C 1.4 × 9.8 mN/d	2.2	8.0
		170 ± 5°C 0.7 × 9.8 mN/d	2.0	5.0
Twisting coefficient			0.49	0.49
Road noise (index)			100	96
Rolling resistance (index)			100	103
Flat spot (index)			100	96

As seen from Tables 1 and 2, in all of the examples tires 1-6, the road noise and rolling resistance are small and the flat spot property is improved.

Also, the high-speed durability can be largely enhanced in the example tires 3 and 4 in which 100% modulus of the coating rubber is 2.5 and 3.0 MPa and the rebound resilience is 60 and 65%, respectively.

INDUSTRIAL APPLICABILITY

According to the invention, as seen from the above examples, when the reinforcing cord constituting the belt reinforcing layer is a cord of polyethylene-2,6-naphthalate fiber having a count of not more than 2400 dtex, the road noise, rolling resistance and flat spot can be largely reduced irrespectively of the structure of the belt reinforcing layer as compared with the

case of using PEN cord of 3340 dtex or nylon cord of 2800 dtex.

Also, the high-speed durability of the tire can be largely improved by specifying the properties of the coating rubber for the reinforcing cord.